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AGE-RELATIONSHIPS OF NEWER BASALTS IN THE GEELONG DISTRICT, VICTORIA

By Alan Coulson*†

Abstract: In the Geelong District four types of Newer Basalt occur, viz. Trentham, Malmsbury, Footscray and Ballan types, ranging in age from Middle or Upper Pliocene to Lower Pleistocene. This paper is concerned with a confined flow of Trentham type along the north bank of the Barwon River, and its relation to the other types.

INTRODUCTION

The Geelong Geological Sheet No. 857 (1:63,360) published by the Geological Survey of Victoria in 1963, shows a confined basalt flow marked Nv2, Newer Volcanic 'Valley basalt', along the Barwon River from Pollocksford to St. Albans. Seven further exposures have been found between Pollocksford and Inverleigh, two east of Winchelsea, and one near the Avalon Overpass on the Geelong-Melbourne Road. The age of this Nv2 basalt, which is of Trentham type (Edwards 1938) is discussed in relation to the adjacent flows of Nv1 'Sheet' basalts, not differentiated on the official map, but here distinguished as Ballan, Footscray and Malmsbury types (Fig. 1).

The method of investigation was field observation and optical petrography. About 400 thin sections were prepared, and are now deposited at the Geology School of the University of Melbourne. Some slides were made at the Gordon Institute of Technology by courtesy of Mr. S. E. Rowe, Lecturer in Geology. Dr. D. Spencer-Jones, Director of the Geological Survey of Victoria, assisted with information and criticism. Much help was received from Dr. A. Cundari and Dr. O. P. Singleton (Melbourne University), and Dr. J. M. Bowler (A.N.U., Canberra). Dr. Bowler kindly allowed the use of his unpublished manuscript on the formation of iddingsite. The co-operation of quarry managers and property owners was also appreciated.

PETROGRAPHY OF THE Nv2 TRENTHAM-TYPE BASALT

Fresh specimens from the interior of the flows are black, greenish-black or dark grey, non-vesicular, with short glittering plagioclase crystals. Thin sections reveal corroded or partly rounded clear olivine crystals, not iddingsitized, sub-hedral pyroxenes, short laths of labradorite (Ab_{32} to Ab_{38}) and a dark groundmass of felspar laths, pyroxene prisms and black glass containing microliths of ilmenite and magnetite. Green felspathic material occurs in some slides from lower portions of flows.

The upper flow units yield specimens which have the olivine crystals lightly margined with yellow or red-brown iddingsite, with less glass, thin rods or blebs of iron ore, but the texture and other minerals remain as in the Trentham basalt.

The virtual absence of iddingsite from the margins of the olivine phenocrysts in the Nv2 valley basalt enables it to be readily recognized in hand specimens as well as in thin sections. The presence of iddingsitized olivine in the upper zones of Nv2, and uniformly throughout the thin sheet flows of Nv1 basalt has been explained (Gay & Le Maitre 1961) as occurring at the deuteric stage, after the flow had come to rest but before the consolidation of the magma, at intermediate temperatures and in a strong oxidizing atmosphere. 'Iddingsite is not a mineral with a definite structure and chemical composition, neither is it a simple sub-microscopic intergrowth of two or more well-characterized minerals' (Gay & Le Maitre 1961). These were thought to be goethite and smectite-chlorite.

According to Bowler (1961), 'the mechanism of iddingsite formation is that the olivine is rich in MgO (Fa_{13},Fo_{87}) and after crystallization some olivine sinks through the fluid centre, causing the residual liquid and volatiles to begin to rise towards the top. Falling temperatures increase the viscosity at top and bottom, pyroxenes crystallize and olivines are partially redissolved with preferential resorption of MgO and SiO_2, leaving the depleted lattices in a disordered state. Near the top of the flow, the remaining FeO is oxidized *in situ* to goethite whilst the remaining SiO_2 takes up CaO

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and Al_2O_3 from the residual liquid to form a layered silicate structure alongside fibrous lamellae of goethite. Deeper in the flow, at higher temperatures, the olivine lattice, with rims depleted in MgO, exsolves excessive iron as magnetite, or incorporates iron into the depleted lattice, resulting in an iron-rich rim.'

Dr. Bowler has supplied the following chemical evidence (Tables 1-3) in support of his theory. (Analysts V. Biskupsky and J. M. Bowler.)

TABLE 1

A. Nv2 VALLEY FLOW, DOG ROCKS, BATESFORD.
B. Nv1 PLAINS FLOW, EAST BATESFORD

	A	B
SiO_2	50.65	51.57
Al_2O_3	13.97	15.51
Fe_2O_3	2.20	6.59
FeO	8.42	4.20
CaO	8.61	8.42
MgO	8.70	4.60
Na_2O	2.10	2.20
K_2O	1.30	0.98
$Ti\ O_2$	1.75	1.75
H_2O-110°	0.94	1.65
H_2O+110°	0.50	1.71
	99.14	99.18

It will be noted that 1. the degree of alteration of olivine to iddingsite decreases with depth. 2. the modal percentage of olivine increases with depth. 3. the percentages of Ca and Mg increase with depth. 4. the percentages of SiO_2 and Al_2O_3 decrease slightly with depth.

Weathered specimens and deep bore cores often contain secondary calcite or aragonite, zeolites, reddish limonite, some siderite and occasional serpentine.

TABLE 3

PARTIAL ANALYSIS OF AVERAGE Nv2 SAMPLES REPRESENTING UPPER, MIDDLE AND LOWER ZONES IN BORE 13, GHERINGHAP, 1 KM WEST OF FYANSFORD.

	Upper Zone	Middle Zone	Lower Zone
Ca O	6.96	7.80	6.06
Mg O	6.73	7.23	8.28
Fe O	5.58	5.57	6.80
Fe_2O_3	4.00	2.75	2.64

AGE OF THE Nv2 FLOW

Near Pollocksford the Nv2 rests on Moorabool Viaduct Sands, usually regarded as Lower Pliocene, but possibly Upper Miocene in age (T. A. Darragh quoted in Aziz-ur-Rahman & McDougall 1972). Between Pollocksford and Fyansford the Nv2 rests on Moorabool Viaduct Sands on the north bank of the Barwon River and on Lower Cretaceous sediments on the south bank. From Fyansford through Newtown the Nv2 fills a valley cut in Lower Cretaceous sandstone and conglomerate. Near Kardinia Park in Latrobe Terrace, Chilwell, the sub-basaltic formation is Moorabool Viaduct Sands (as proved by borings of the Geelong Waterworks and Sewerage Trust). Between Fyansford and Batesford the Nv2 rests on eroded Fyansford Clay (Bairnsdalian) or on Devonian granite at the Dog Rocks.

Thin Quaternary gravels and sands cover the Nv2 in places between Batesford and Fyansford, also at Breakwater and St. Albans. At Batesford Australian Portland Cement Ltd. quarry there was a capping, now removed, of 1 m of sandy limestone chemically deposited in surface depressions on the Nv2; it resembled the Lara limestone of Pleistocene age (Pritchard 1895) but contained no fossils.

TABLE 2

ANALYSES OF Nv2 BASALT AT VARIOUS DEPTHS IN GHERINGHAP BORE 15, 1 KM WEST OF FYANSFORD, ON HAMILTON HIGHWAY.

Depth	3.0 m	16.4 m	24.3 m	32.3 m	38.1 m	40.8 m	45.1 m
$Si\ O_2$	51.08		48.57	50.95		49.74	49.65
Al_2O_3	15.10		13.35	14.04		13.50	12.95
$Fe_2\ O_3$	4.33	4.49	3.44	3.95	3.08	1.60	4.49
Fe O	5.38	6.08	7.00	6.50	7.60	9.36	6.24
Ca O	8.34	6.48	7.40	7.80	7.33	8.38	8.17
Mg O	6.10	8.66	9.52	4.95	9.63	9.79	7.50
$Na_2\ O$	3.68		3.69	4.38		3.68	3.84
$K_2\ O$	1.32		1.31	2.42		1.75	1.75
$Ti\ O_2$	1.65		1.60	2.40		1.80	1.78
H_2O-110°	1.11		1.95	1.21		0.19	0.97
H_2O + 110°	1.25		1.50	1.40		0.15	1.75
	99.41		99.33	100.07		99.94	99.19

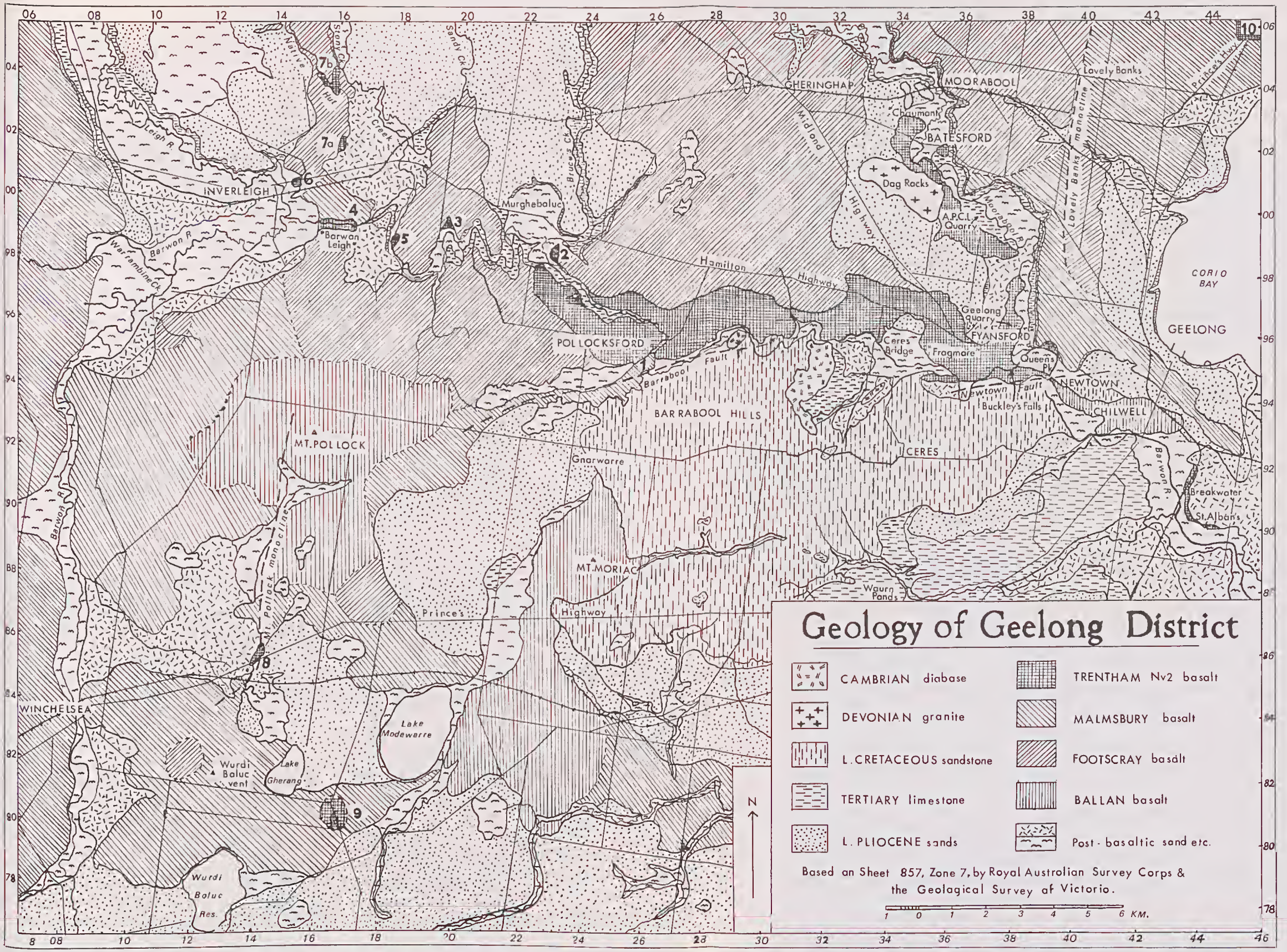

FIG. 1. Geology of Geelong District.

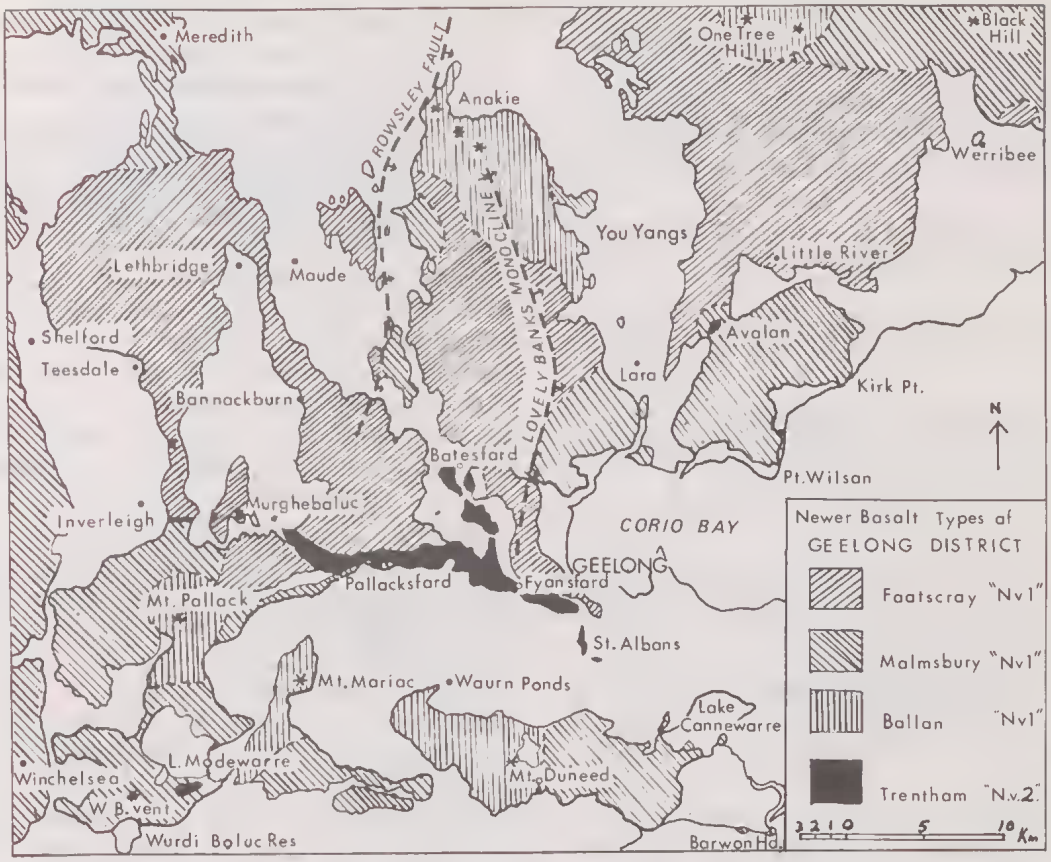

FIG. 2.—Distribution of Newer Volcanic types in Geelong District.

If the suggested Upper Miocene age of the Moorabool Viaduct sands is accepted, it provides a longer time-interval for the extrusion of the Newer Volcanic flows, say from Middle Pliocene to Lower Pleistocene. The K-Ar radiometric age of 2.1 million years (Aziz-ur-Rahman & McDougall 1972) on Nv2 samples from Pollocksford and Fyansford would place it in the Upper Pliocene at the latest; its stratigraphic position could be Middle or Upper Pliocene.

EXTENT OF THE Nv2 FLOW

The Nv2 flow as mapped (Fig. 1) extends from 5 km west of Pollocksford (altitude 60 m) along the Barwon River to Fyansford (altitude 45 m) through Newtown (altitude 36 m) and Chilwell (altitude 20 m) to Breakwater and St. Albans (altitude 8 m), a distance of 19 km (Fig. 1). A flow of Nv2 runs north from Fyansford to Batesford, a distance of 6 km, but has been severely eroded by the Moorabool River into four residuals overlain in places by gravel and sands.

The thickness of the Nv2 varies considerably, being 35 m at Pollocksford, 20 m near Ceres Bridge, 46 m in Gheringhap Bore 20 at Fyansford, 30 m in Geelong Quarry at North Fyansford, 15 m at the Dog Rocks, and 10 to 15 m at the Australian Portland Cement Ltd. quarry at Batesford. The Nv2 basalt forms the river bed at Pollocksford Bridge, the property 'Barwon Leigh', and at Buckleys Falls, Fyansford.

Three flow units can be discerned in Geelong Quarry, three at Buckleys Falls, two in Fyansford and Newtown quarries, and three in the Gheringhap bores in 'Frogmore' west of Fyansford (Fig. 3). Each unit consists of an upper vesicular zone about 2 m thick, columnar basalt 5 to 12 m thick, and a thin glassy base. The vesicular zone about 2 m thick, columnar basalt 5 to 12 m thick, and a thin glassy base. The vesicular zone is usually marked by partially iddingsitized olivines resulting in a more brownish colour in the rock.

FURTHER EXPOSURES OF Nv2 BASALT

The following exposures have been located; numbers correspond to Fig. 1.

Locality 1. 50 m W. of Pollocksford Bridge, in cutting on S. side of Gnarwarre Road. Corestones in 'onion structures' are Nv2., overlain by Footscray type. Military Co-ordinates (hereafter M.C.) 262951. Altitude (hereafter Alt.) 33 m.

Locality 2. 2 km SE. of Murgheboluc, on spur near junction of Bruces Creek and Barwon River. Upper flow is Malmsbury type. M.C. 219986. Alt. 60 m.

Locality 3. 2 km SW. of Murgheboluc, in gully on 'View Bank' farm, N. bank of Barwon River. M.C. 195993. Alt. 45 m. Upper flow is Malmsbury, probably from Mt. Pollock.

Locality 4. 'Barwon Leigh.' 2 km SE. of Inverleigh, basalt bar 1 km wide in Barwon River. M.C. 165992. Alt. 56 m.

Locality 5. E. bank of Barwon River opposite 'Barwon Leigh'. M.C. 181993. Alt. 50 m. Upper flow is Footscray type.

Locality 6. Inverleigh Picnic Reserve, E. bank of Leigh River in road cutting. M.C. 144006. Alt. 59 m. Upper flow is Footscray type from Stony Creek flow.

Locality 7. (a) Inverleigh, E. of Golf Course. M.C. 152023. Alt. 53 m.

(b) Inverleigh, junction of Stony Creek and Native Hut Creek, in bed of creek, overlain by Footscray type. M.C. 158033. Alt. 57 m.

Locality 8. Prince's Highway, 1 km E. of road bridge over railway E. of Winchelsea. M.C. 139852. Alt. 105 m. Mt. Pollock Monocline crosses the road at this point, tilting lava to W. Corestones in onion structures; associated with fine Malmsbury type.

Locality 9. Between Lake Modewarre and Wurdi Boluc Reservoir. M.C. 162802. Alt. 126 m. About 1 sq. km of Nv2 is exposed here, and may be an early flow from the Wurdi Boluc vent about 3 km to the W.

Locality 10. (a) Prince's Highway, disused quarry at W. end of Avalon Overpass. M.C. 531117. Alt. 17 m. Upper flow is Malmsbury type. Radiometric age of upper flow is 1.6 million years, (Aziz-ur-Rahman & McDougall 1972).

(b) Same locality, Woornyalook Bores 2,3. Nv2 below 20 m depth. Upper flows are Footscray and Malmsbury types, probably from the Balliang group of vents to the N.

Superposition is demonstrable at localities 3, 5 and 7, where in each case the Nv2 is overlain by Footscray or Malmsbury type sheet-flows. Other instances of superposition occur at (i) Stonehaven, in a gully running south through the property 'Springdale' to the Barwon River. M.C. 307963. Here Footscray type overlies Nv2. (ii) in a gully north of Pollocksford Bridge. M.C. 267958. Here a similar relation exists. (iii) Breakwater Railway Crossing. M.C. 437917. Malmsbury type overlies the Nv2.

The width of the exposed Nv2 between Murgheboluc and Fyansford varies between 1 and 2 km, the junction between Nv1 and Nv2 is irregular, and the surface of the Nv2 is usually several metres lower than the Nv1.

It is necessary to explain why the Nv1 does not overlap the Nv2 right up to the Barwon River. One reason is that in many places the Nv1 did not extend further than its present limits. The other is that erosion has removed the thin southern edges of the Nv1 flows.

A more serious difficulty is that the upper flow-units of Nv2 are often iddingsite-bearing, thus resembling Footscray type. This makes it necessary to examine the basalt underlying the surface type to decide if it is Nv2 or Nv1. If both surface and underlying rock is Nv1, then the whole is mapped as Nv1. If the under-rock is Nv2, and the surface rock is apparently Nv1 but thin, it is mapped as Nv2. For this reason the official mapping has been followed in classifying as Nv2 rather than Footscray, the surface basalt near the south end of Dears Lane, the low ridge 50 m east of Stonehaven Primary School, and near the north end of Pollocksford Road.

It will be realized from the foregoing that, at least in the area between Inverleigh and Fyansford, the Nv2 is older than the Footscray and Malmsbury types there. Does the same age-relationship hold for the Nv2 of the Batesford-Fyansford tongue flow? East of Batesford Bridge the lower flow is a residual of an Nv2 flow which filled a valley of the ancestral Moorabool River. Its surface level is 46 m, whilst the upper level Nv1 sheet flow is at 61 m, and the bank has receded 300 to 350 m east of the river (Fig. 3). Just after extrusion the Nv1 must have extended to the east flank of the Dog Rocks. Erosion by the Moorabool River has removed the upper basalt from the western edge of the flow, and exposed the Moorabool Viaduct Sands and the Fyansford Clay.

The upper level Nv1 sheet-flows at Batesford probably came from eruption centres near Anakie, and as they ante-date the Nv2 there, must be older than 2.1 million years, i.e. they must have been extruded in Lower or Middle Pliocene times, and would thus be the earliest of the 'Newer' basalts (cf. Spencer-Jones 1970). They are overlain by freshwater limestone of Pleistocene age at Lara, and in general are more weathered than the Nv1 types to the west of the Moorabool River.

There is no evidence of Nv2 in the valleys of the upper Moorabool River or Sutherlands Creek, nor in the valley of Cowie's Creek; the Nv2 terminates at the property 'Chaumont' 1 km north-west of Batesford. At the east end of the Moorabool Viaduct there is a quarry (Bowler 1963) at a level 15 m below the surface of the upper Nv1 flows, but the rock is Footscray type filling a small valley on the pre-basaltic surface. No connection has been found between the Batesford Nv2 and the Avalon Nv2 despite search in the valleys of Cowies Creek, and Hovells Creek. An alternative source of the Batesford Nv2 is that it came upstream from Fyansford, a distance of 6 km. The maximum

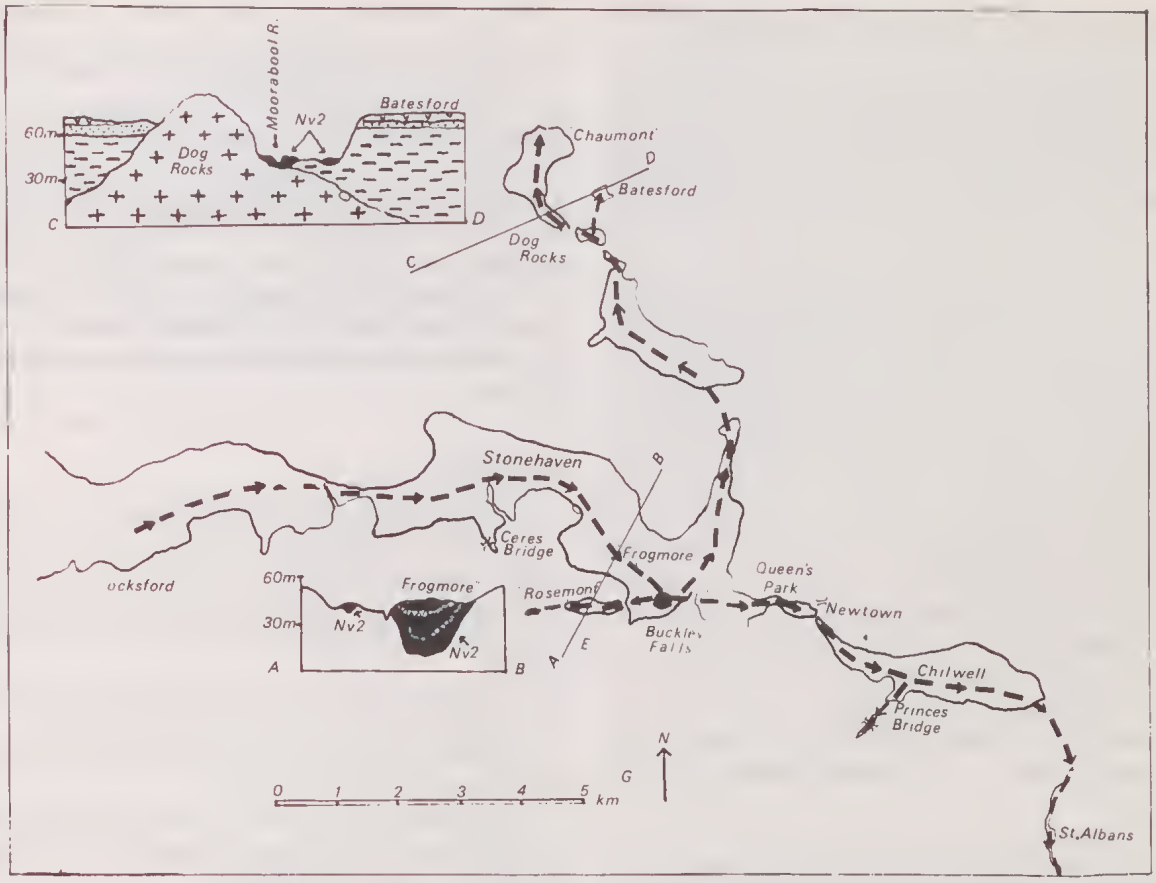

FIG. 3.—Possible course of Nv2 lava filling valley of ancestral Barwon River.

thickness of Nv2 at Fyansford (Gheringhap Bore 20) is 46 m and at Batesford 33 m. It is suggested that the early Nv2 flow units from Pollocksford partly filled, to say 34 m, a deep hole at Buckleys Falls, Fyansford, then occupied the former Barwon River valley (Fig. 3) through Newtown and Chilwell to St. Albans. Further flows of Nv2 on reaching Fyansford were diverted northwards, filling the valley of the ancestral Moorabool River to about 46 m altitude, and terminating at North Batesford. Some support for this theory is that there are three flow units visible in the east face of Buckleys Falls, each approximately 15 m thick. The upper flow shows crudely columnar structure, and it was possibly part of this flow which reached Batesford.

ORIGIN AND EMPLACEMENT OF THE Nv2 FLOWS

The source of the Pollocksford Nv2 has not been definitely located. Two localities that suggest themselves are (i) Locality 7(b), just north of the junction of Native Hut and Stony Creeks. This exposure is covered by a very young flow of Footscray type from the Teesdale area. (ii) Locality 9, between Wurdi Boluc Reservoir and Lake Modewarre. This outcrop is surrounded and partly covered by the fine Malmsbury type from the Wurdi Boluc lava dome 3 km to the west. This locality is 14 km south of the Inverleigh exposures, but no connection can be traced between them except for the limited exposure at Locality 8.

The Nv2 is pictured as emanating north of Inverleigh, flowing south to 'Barwon Leigh', then turning east along the valley of the ancestral Barwon at the foot of the Barrabool Fault scarp and the Newtown Fault scarp to Fyansford. The main flow continued through Newtown to St. Albans, whilst a shorter flow moved north up the Moorabool valley to Batesford. The Barwon River was displaced further south as a result of the infilling of its former valley by the Nv2, and cut its present valley, causing recession of the northern face of the horst. Some of the infilled tributaries, e.g. south of 'Frogmore' near Ceres Bridge, and east of Princes Bridge at Marnock Vale, formed temporary barrier lakes until cut by the rejuvenated Barwon River. Similarly Queens Park was a lake until breached by the Barwon at Newtown (Fig. 3).

After the Nv2 had solidified, the Nv1 flows began to